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Ignition-relevant high-temperature hohlraum plasmas show efficient laser beam propagation

We have demonstrated efficient intense laser beam propagation in a newly developed high-electron-temperature, long plasma column. This was accomplished by uniformly heating 2-mm-long, low-Z gas-filled or foam-filled cylindrical hohlraums with up to 38 blue (3ω) laser beams and measuring the transmission and scattering properties of an intense green (2ω) interaction beam directed along the hohlraum axis. The experiments show negligible scattering losses and up to the expected 80% 2ω laser beam transmission at the independently measured, ignition hohlraum-relevant highest electron temperatures of $T_e = 3 – 4$ keV. These findings support our indirect-drive ignition designs for NIF that utilize high-electron-temperature low-Z plasmas in the hohlraum interior.

NIF is a 192-beam laser facility under construction at the Lawrence Livermore National Laboratory to ignite and burn deuterium-tritium (DT) plasmas in the laboratory. NIF uses the indirect-drive approach to ICF for compressing and heating the DT fuel contained in small capsules. In this approach, the capsule is placed inside a radiation enclosure, called a hohlraum, whose inside walls are illuminated by the laser beams to produce soft X rays that compress and heat the fuel. To efficiently produce X-rays, the laser beams need to propagate through the hohlraum interior without significant absorption and scattering losses before they reach the hohlraum walls. A high-temperature, low-Z plasma fill minimizes these losses.

In recent experiments performed at the OMEGA laser at the University of Rochester, we have first developed a new high-electron-temperature hohlraum platform and subsequently demonstrated efficient laser beam propagation at electron temperatures of $T_e = 3 – 4$ keV that approach those calculated in present ignition hohlraum designs. Figure 1 shows a schematic of these experiments. The plasma electron and ion temperature was measured by 4ω spectrally resolved laser "Thomson" scattering on separate shots. In the experiments, we measured the transmission and forward scattering of a spatially smoothed interaction beam and the laser backscattering (consisting of stimulated

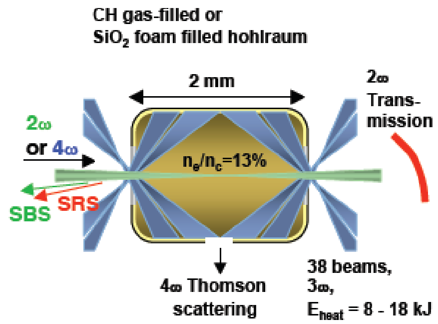

Figure 1. Schematic of 2ω laser beam propagation experiment through a high-electron-temperature hohlraum target that yields up to 80% transmission. Replacing the green (2ω) interaction beam with an ultraviolet (4ω), Thomson scattering probe allows accurate measurements of the high electron temperatures present in these targets. The density is $n_e = 5 \times 10^{20}$ cm^{-3}.

Brillouin scattering [SBS] and Raman scattering [SRS]) using a full aperture backscattering station and a near backscattering imaging diagnostic. Compared to previous laser–plasma interaction studies, the present target has reached hohlraum relevant ignition temperature conditions because more heater beam laser energy could be delivered to the target heating a smaller volume over a scale length of 2 mm (Fig. 2). In addition, by reducing the heater beam energy, lower temperature conditions could be accessed to determine the threshold for the onset of scattering

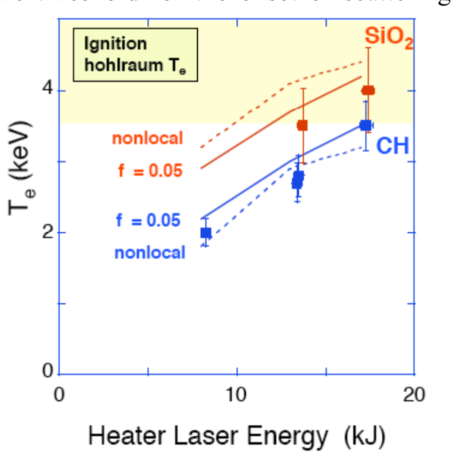

Figure 2. Peak electron temperature is shown as measured with Thomson scattering indicating that ignition hohlraum conditions are approached for heater beam energies of E > 15kJ. Further shown are results from radiation hydrodynamics modeling with the code HYDRA using two different heat transport models. Good agreement is observed.

losses. Our first tests of beam propagation in this new high-temperature hohlraum fill plasma have been performed with a 2ω interaction beam and are relevant to future ignition designs where the hohlraum is heated with green light rather than blue. Using a green interaction beam is also expected to increase the effects of absorption and scattering. Figure 3 shows the results from the 2ω transmission measurements for various electron temperatures together with simulation results. While low electron temperature plasmas of 2 keV show less than calculated transmission and significant scattering losses whose non-linear dependences are difficult to include in the modeling, we observe 80% transmission for ignition conditions in close agreement with modeling. This finding suggests

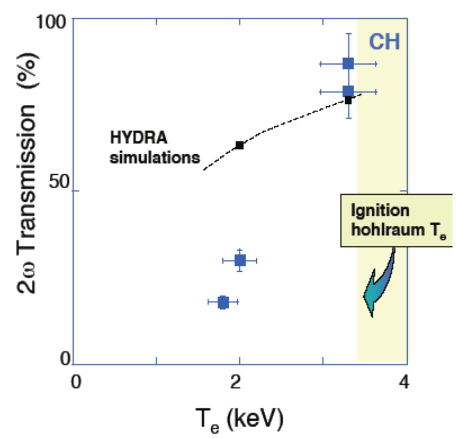

Figure 3: Measurements of the transmission of the 2ω interaction beam (averaged over 200 ps at the end of the heating pulse) through the gas-filled hohlraum (CH) as function of the electron temperature. At the highest temperature, we observe 80% transmission close to calculations using the code HYDRA. At low temperatures, the experiment shows less transmission due to the onset of laser backscattering by SRS.

that 2ω scattering losses at ignition-relevant hohlraum plasma electron temperatures are suppressed by "Landau" damping of collective plasma oscillations initially set up by the intense laser field-plasma interaction. We can therefore expect that existing modeling calculating adequate beam propagation in future ignition hohlraums heated with 2ω beams on NIF will be valid. Experiments to measure transmission of a 3ω interaction beam relevant to our point design for 2010, will be performed over the next year.

For comments about content of the ***Bimonthly Update,*** contact Bruce A. Hammel (925) 422-3299.
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